AKB 12 Soft-Matter Nanofluidic Devices

Time: Tuesday 14:00–16:00 Room: ZEU 255

Invited Talk

AKB 12.1 Tue 14:00 ZEU 255

Transport and Reaction-Diffusion Phenomena in Soft-Matter Nanofluidic Devices — •Owe Orwar — Department of Chemistry and Biotechnology, Chalmers University of Technology, SE-412 96 G*teborg, Sweden

Methods for the construction of fluid state lipid bilayer networks consisting of nanotube-conjugated vesicles are presented. Unilamellar vesicles (5-25 μm in diameter) can be connected with nanotubes (30-300 nm in diameter) in a controlled fashion using both self-organization, and forced shape transformations, allowing design of nanofluidic networks of particular geometries and topologies[1-4]. The membrane composition (e.g. lipids, transporters, receptors, and catalytic sites) and container contents (e.g. catalytic particles, organelles, and reactants) can be controlled on the single-container level allowing complex chemical programming of networks [5].

Transport in nanotubes and materials exchange between conjugated containers can be obtained by using three different methods. 1. Marangoni flows where transport is modulated by changes in membrane tension[6-9], 2. electrophoresis [10] where an electric field is applied across nanotubes using Ag/AgCl electrodes inside gel-plugged pipettes, and 3. by diffusional relaxation from systems with pre-programmed chemical potential. All these transport modes can be combined with confocal microscopy and sensitive APD detectors, for single-molecule interrogation. For example, electrophoretic transport and single-molecule detection of large DNA molecules while confined in the lipid nanotube was achieved [10].

Thus, networks of nanotubes and vesicles serve as a platform to build nanofluidic devices operating with single molecules and particles and offers new opportunities to study chemistry in confined biomimetic compartments. As an example, we demonstrate that a transition from a compact geometry (sphere) to a structured geometry (several spheres connected by nanoconduits) induces an ordinary enzyme-catalyzed reaction to display wave-like properties. The reaction dynamics can be directly controlled by the geometry of the network and such networks can be used to generate various wave-like patterns in product formation. The results have bearing for understanding catalytic reactions in biological systems as well as for designing emerging wet chemical nanotechnological devices.

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AKB 12.2 Tue 14:30 ZEU 255

Microaligned collagen matrices by hydrodynamic focusing — •Sarah Köster[1,2], Jennie Leach[2,3], Bernd Struth[4], Joyce Wong[2], and Thomas Pfohl[1] — [1]Max Planck Institute for Dynamics and Self-Organisation, Bunsenstraße 10, 37073 Göttingen, Germany — [2]Department of Biomedical Engineering, Boston University, Boston, MA, USA — [3]University of Maryland Baltimore County, Chemical and Biochemical Engineering, Baltimore, MD, USA — [4]European Synchrotron Radiation Facitlity, 6 rue Horovitz, B. P. 220, 38043 Grenoble Cedex, France

The hierarchical structure of type I collagen fibrils is a key contributor to the mechanical properties of the extracellular matrix (ECM). To date, there are few methods available for precisely controlling and investigating collagen fibril assembly. The objective of this work was to create highly aligned collagen substrata to systematically determine the effects of microscale collagen alignment on cellular behavior. We use a microfluidic diffusive mixing device to create a defined pH gradient, which in turn initiates the self-assembly and concurrent alignment of soluble collagen. Our method enables us to investigate collagen assembly using polarized light microscopy and x-ray microdiffraction. Finite element method simulations of the hydrodynamic and diffusive phenomena predicted feasible operating conditions for tuning collagen fibrillogenesis and were verified experimentally. Furthermore, substrates prepared by using this technique can be used as scaffolds for cell growth. Anisotropic collagen induces alignment of the cytoskeleton and may facilitate the study of its interactions with the ECM.

AKB 12.3 Tue 14:45 ZEU 255

Evolution of DNA compaction in microchannels — •Rolf Dootz[1], Alexander Otten[2], Sarah Köster[1], Bernd Struth[3], and Thomas Pfohl[1] — [1]Max Planck Institute for Dynamics and Self-Organization, Bunsenstraße 10, 37073 Göttingen, Germany — [2]Applied Physics Department, University of Ulm, Albert-Einstein-Allee 11, 89069 Ulm, Germany — [3]European Synchrotron Radiation Facility, 6 rue Horovitz, BP 220, 38043 Grenoble, France

Combining microfluidics with X-ray microdiffraction and Raman microscopy, the dynamic behaviour of soft matter in specific consideration of the molecular structure can be investigated. Owing to the generated elongational flow, alignment of the investigated materials is induced which allows for an improved structural characterisation. Here, the dynamics of the compaction of DNA by polyimine dendrimers is studied. Due to the laminar flow inside the microchannels, a highly defined, diffusion controlled compaction of the DNA occurs enabling the study of different states of the reaction during one measurement by varying the observation position in the channels. The evolution of a columnar mesophase with an in-plane square symmetry is monitored by X-ray microdiffraction and the molecular interaction between the two reactants is traced using Raman microscopy leading to a more profound comprehension of the condensation reaction.

AKB 12.4 Tue 15:00 ZEU 255

Vesicle deformation in shear and capillary flows — •Hiroshi Noguchi and Gerhard Gompper — Institut fuer Forstkoeperforschung, Forschungszentrum Juelich 52425 Juelich, Germany

We study the dynamics of vesicles in shear flow and in micro-channels. A new simulation technique is presented, which combines a three-dimensional mesoscale simulation technique, multi-particle collision dynamics[1] for the solvent with a dynamically-triangulated surface membrane model. The deformation of vesicles is an important subject not only of fundamental research but also in medical applications. For example, in microcirculation, the deformation of red blood cells reduces the flow resistance of microvessels. We focus the effects of membrane viscosity in shear flow [2,3] and the effects of the shear elasticity and bending modulus of membrane in capillary flow [4]. We have found several shape transtions. In capillary flow, an elastic vesicle (red-blood-cell model) transits from a discocyte to parachute-like shape, while the fluid vesicle transits into prolate with increasing flow rate. In both cases, the shape transitions reduce the flow resistance.

[1] A. Malevanets and R. Kapral, J. Chem. Phys. 110, 8605 (1999)
[2] H. Noguchi and G. Gompper, Phys. Rev. Lett. 93, 258102 (2004)
[3] H. Noguchi and G. Gompper, Phys. Rev. E 72, 011901 (2005)

[4] H. Noguchi and G. Gompper, Proc. Nat. Acad. Sci. USA 102, 1415993 (2005)

AKB 12.5 Tue 15:15 ZEU 255

High-Throughput Microfluidic Delivery of Suspended Cells for Marker-Free Deformability Measurement — •Bryan Lincoln — Institute for Soft Matter Physics, University of Leipzig, Linne'strasse 5, 04317 Leipzig

Microfluidic channels typically have the advantage of being laminar flow systems, meaning that are both reversible and linear. This enables their use as an efficient method of cellular transport. By incorporating a dual-beam laser trap, or optical stretcher, into a capillary-based microfluidic chamber, suspended cells can be serially delivered to the trap location where they undergo a step-stress deformation experiment. This deformability is a sensitive, quantitative measure of a cell's global cytoskeletal organization and can be used to track cytoskeletal alterations during both physiological and pathological changes. Applications include the study of the progression of cancer, the differentiation of stem cells, the effects of cell culture conditions and cell cycle, and the evolution of primary cells in culture. This is a marker-free technique with potential for efficient sorting with minimal damage.

AKB 12.6 Tue 15:30 ZEU 255

Heating effects in dual beam laser traps — •Susanne Ebert, Kort Travis, and Jochen Guck — Universität Leipzig, Department of Soft Matter Physics, Linnéstr. 5, 04103 Leipzig, Germany

Dual beam laser traps in a microfluidic environment are a very useful tool for noninvasive handling and manipulation of cells and similar objects. Due to the low energy density of the divergent trapping beams, heating effects are expected to be rather small but cannot be generally excluded.

We applied a fluorescence intensity ratio technique using rhodamineB and rhodamine110 to measure spatial temperature profiles in a microfluidic setup with a confocal laser scanning microscope. The data, taken for two different wavelengths (1064 nm and 780 nm), will be compared to theoretical models and to measurements taken with a thermosensitive camera.

AKB 12.7 Tue 15:45 ZEU 255

Hydrodynamics of Sperm Motion near Hard Walls — •Jens Elgeti and Gerhard Gompper — Forschungszentrum Jülich, Institut für Festkörperforschung, 52425 Jülich

Sperm cells are propelled in a fluid by an active, snake-like motion of its tail, the flagellum. It is already known for some time experimentally that cells accumulate at a wall, swimming always in clockwise circles.

We investigate the sperm motion in a film geometry theoretically. The sperm tail is modelled as a semi-flexible polymer, which is subjected to a sinusoidal bending force. The sperm head is modeled as a sphere, asymmetrically displaced from the beat plane of the tail. Hydrodynamic interactions, which are responsible for the directed motion of the cell, are taken into account by a particle-based, mesoscopic simulation technique (multi-particle collision dynamics).

We show that this highly simplified model captures the basic features of cell motion described above. This shows that hydrodynamic interactions are responsible for the effective attraction to a wall.

Tuning the asymmetry, we find three different types of motion, which are characterized by different radii of curvature, different distance distributions from the wall, and different angles between the beat plane and the wall. Finally, we compare our results with experimental data.